New Zealand Journal of Ecology (2023) 47(1): 3501 © 2023 New Zealand Ecological Society.

NEW ZEALAND JOURNAL OF ECOLOGY

RESEARCH

Evaluating the effectiveness of a feral cat control operation using camera traps

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Published online: 14 October 2022

Abstract: Feral cats (*Felis catus*) have a negative impact on native biodiversity in New Zealand. As such, their populations require careful management and monitoring of the effectiveness of these management operations. We used camera traps to assess (1) effectiveness of an intensive cat control operation, and (2) the level of reinvasion six months later. Cat abundance was estimated on a pastoral property in Hawke's Bay, North Island, New Zealand, subject to cat control using trapping and shooting. Forty cameras were placed on a grid with 500 m spacing and deployed for a total of nine weeks: (1) pre-control, (2) immediately post-control, and (3) six-months post control. Cat abundance was estimated using an index-manipulation-index (IMI) method. The IMI method estimated an c. 84% decrease in cat abundance immediately post-control, suggesting the operation worked well at removing most resident cats at this site. The detections observed six months later suggest reinvasion was very low.

Keywords: camera traps, feral cats, invasive species, monitoring, reinvasion

Introduction

Feral cats (*Felis catus*) have a negative impact on native wildlife globally (Medina et al. 2011; Doherty et al. 2017). As such, lethal control of feral cats is carried out to protect native species and increase biodiversity (Doherty et al. 2015; Doherty & Ritchie 2017; de Burgh et al. 2021). Cats arrived in New Zealand with European explorers in the latter part of the 18th century and are now found in most habitats throughout New Zealand (Alterio et al. 1998; Gillies & van Heezik 2021). They are routinely targeted during predator control operations in New Zealand (Gillies & van Heezik 2021) due to their negative impacts on native wildlife through predation and disease (Dickman 2015). Common methods for feral cat removal include leg-hold and cage trapping, shooting, hunting with dogs, and poison baiting (Parkes et al. 2014; Algar et al. 2020).

Efficient monitoring following control operations is vital to the success of invasive species management (Doherty & Ritchie 2017; Dilks et al. 2020; Nichols et al. 2021). Camera trapping is often used as a non-invasive method for monitoring elusive species (Bengsen et al. 2011; Dilks et al. 2020; Nichols et al. 2021). Cameras can provide important information on animal activity (Garvey et al. 2017) and can be used to identify individual animals (Karanth & Nichols 1998). Cameras can be useful for detecting species such as feral cats at very low densities (Glen et al. 2016; Nichols et al. 2019). Feral cats are often identifiable through colour coat patterns (Gillies & van Heezik 2021); however, black, tabby, and ginger colours are the most common in local populations (Gillies & van Heezik 2021).

This study used the index-manipulation-index (IMI) method (Bayliss & Yeomans 1989; Fryxell et al. 2014) to estimate feral cat abundance changes after an intensive control operation at a pastoral site. This method does not require unique identification of individuals in the population. The control operation utilised a combination of cage, leg-hold, and kill traps as lethal control methods. The same camera traps were used again six months later to determine the extent of reinvasion across the same site. Understanding both the efficacy of an operation and the rate of reinvasion is important for feral cat management, and subsequently maintaining positive outcomes for biodiversity.

Methods

Monitoring and control methods

Waitere station is a pastoral site in Hawke's Bay, North Island, New Zealand (c. 39º S, 176º E), with small patches of native bush throughout (Fig. 1). The site had no recent history of predator control. The study took place from April to November

DOI: https://dx.doi.org/10.20417/nzjecol.47.3501

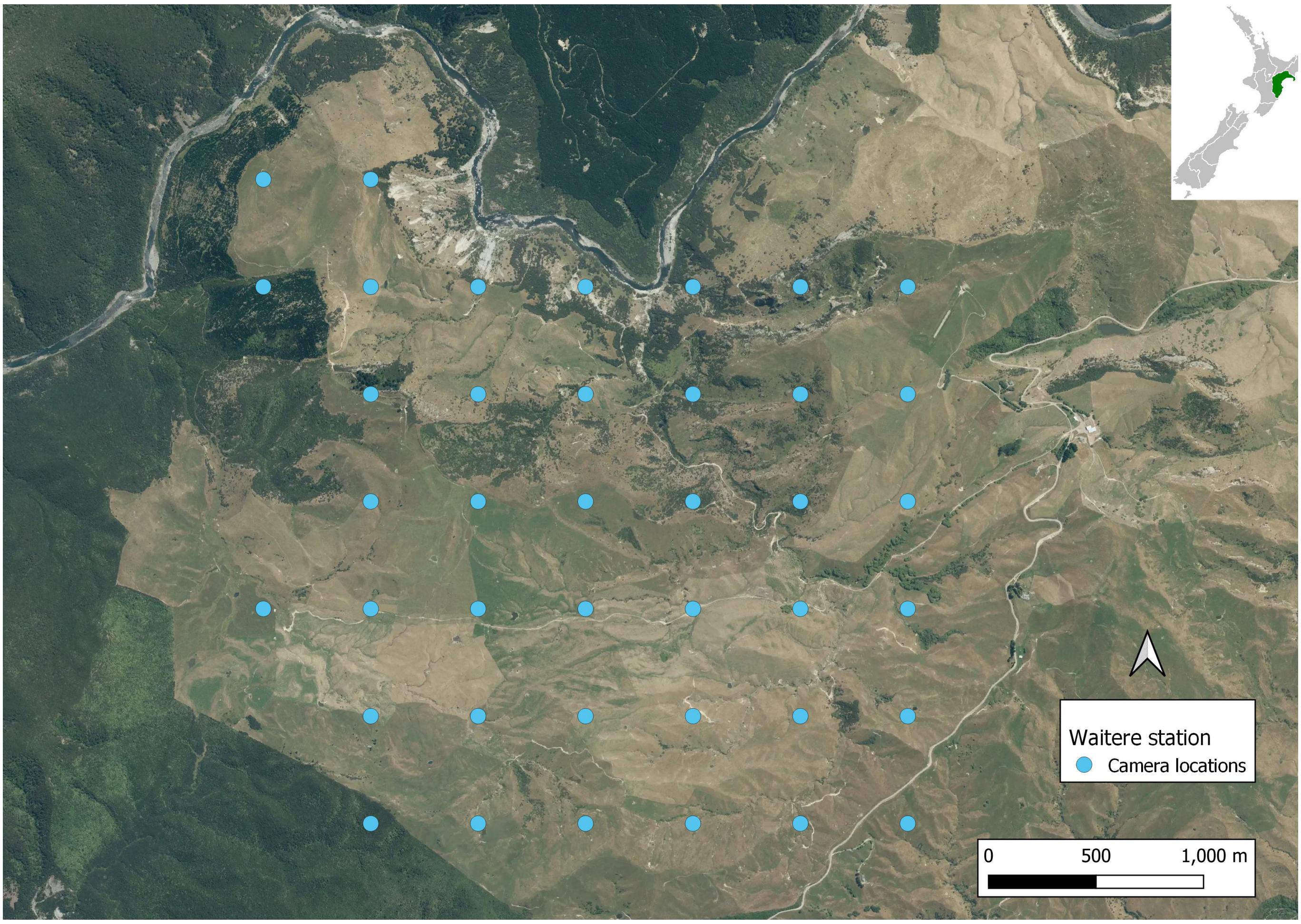

Figure 1. Pre-determined camera trap locations at Waitere station, Hawke's Bay, North Island, New Zealand 2014.

2014. In total, 40 Reconyx PC 900 (RECONYX Inc, Holmen, Wisconsin) cameras were deployed in a 7 km^2 grid with c. 500 m spacing between individual cameras. At 500 m spacing, feral cats were expected to encounter multiple cameras within an average home range (1–2 km^2) for a similar pastoral landscape (Langham & Porter 1991).

All cameras were mounted on wooden stakes, with the base of each camera 7 cm from the ground (Garvey et al. 2017; Nichols et al. 2017). The cameras were set to take a series of three photos per trigger, with no delay between triggers. Camera batteries and SD memory cards were replaced after each monitoring period. A lure of ferret (*Mustela furo*) odour and rabbit (*Oryctolagus cuniculus*) meat was placed in a perforated vial 1.5 m in front of the camera and secured with a tent peg (Garvey et al. 2017; Nichols et al. 2017). Lures were replenished at the start of each monitoring period.

The monitoring periods in the following sections are referred to as 'pre-control', 'immediate post-control', and 'six months post-control'. Data was taken from a total of nine weeks of camera monitoring – three weeks pre-control, three weeks post- control, and three weeks six months after control. The pre-monitoring and control periods took place in late Autumn (April and May), while the immediate post-control and six-months post-control monitoring periods took place in early Winter (June) and late Spring (November) respectively. Kittens are typically born between spring and autumn (Gillies & van Heezik 2021), and dispersing sub-adult males are typically more active in spring (Langham & Porter 1991). Thus, we assume population closure within the pre-monitoring and immediate post-control monitoring periods.

Although feral cats were the primary target species for control, other predators such as mustelids (*Mustela furo*), rats (*Rattus rattus*) and hedgehogs (*Erinaceus europaeus*) were also removed during the operation. Specialist contract trappers removed cats and other species using a combination of cage, leg-hold and kill traps (Possum Master trap). All traps were deployed at a density of 1 per 25 ha within the study site. Traps were checked daily soon after sunrise, captured animals were humanely killed, and all carcasses were collected.

Data analysis

The IMI method estimates absolute abundance of a local population, by obtaining two indices of population size, a baseline estimate, and a second estimate after a known number of animals has been removed (Caughley 1977; Fryxell et al. 2014). This method has been used previously to validate results from other methods of abundance estimation (Bayliss & Yeomans 1989). To obtain accurate results, the population must be closed to all births, deaths, immigration, or emigration (Fryxell et al. 2014). In the current study, we assume that populations were effectively'closed to births, deaths, immigration, and emigration for each 3-week monitoring period. However, we cannot assume closure between the immediate post-control period and the six-month post control period. The term 'immediate' is used to differentiate from the six-month post-control period.

Edwards et al. (2000) suggested the IMI method be used to test the accuracy of other methods for estimating populations of feral cats and other carnivores. The IMI method is generally considered more labour intensive due to the necessity of obtaining two indices for the population estimate (Edwards et al. 2000). It is feasible in the current study, given we have pre- and post-monitoring using camera traps, followed by an intensive removal period where a known number of individuals were removed by contractors.

The population estimate pre-control (Y_1) can be measured as follows:

$$Y_1 = I_1 C / (I_1 - I_2) \qquad (1)$$

I_1 (the pre-control estimate), is calculated from the number of camera sites that detected a cat over the three weeks pre-control, and I_2 (the post-control estimate), is calculated from the number of camera sites that detected a cat over the three weeks post-control, after a known number of individuals were trapped and removed, C (Fryxell et al. 2014). The proportion of animals removed can be defined as $p^* = (I_1 - I_2) / I_1$, with the proportion of animals remaining post-control shown as $q^* = 1 - p^*$. From this, the variance for the population estimate can be calculated by:

$$\mathrm{Var}(Y_1) \approx Y_1^2 (q^*/p^*)^2 (1 / I_1 + 1 / I_2) \qquad (2)$$

Results

Trapping

The contract trappers removed 17 cats during the control period (588 trap nights). While the control period took place over a three-week period, 90% of trapped cats were captured in the first five days; with the last cat captured on the tenth day. Given the short time frame where all cats in the study were trapped, we can assume a high proportion of resident cats were exposed to the trap network. All trap types used showed consistent efficacy for trapping cats.

Camera detection

There was a total of 299 images of cats taken across all three periods (238 of cats pre-control, 31 immediate post-control, and 30 six-months post control). Some of these images may have been the same cat, as individual identifications were not recorded reliably as earlier stated. Cats were detected at 13 of 40 camera locations during the pre-control period (Fig. 2a). In the immediate post-control period, cats were detected at two camera locations on the edge of the study area (Fig. 2b). The two cats that were recorded on the edge of the study area were uniquely identifiable (black and white spots and an orange bullseye tabby). The black and white spotted individual had not been recorded on camera pre-control; and thus, may have invaded the area immediately post-control, or survived the control operation but gone undetected previously. The

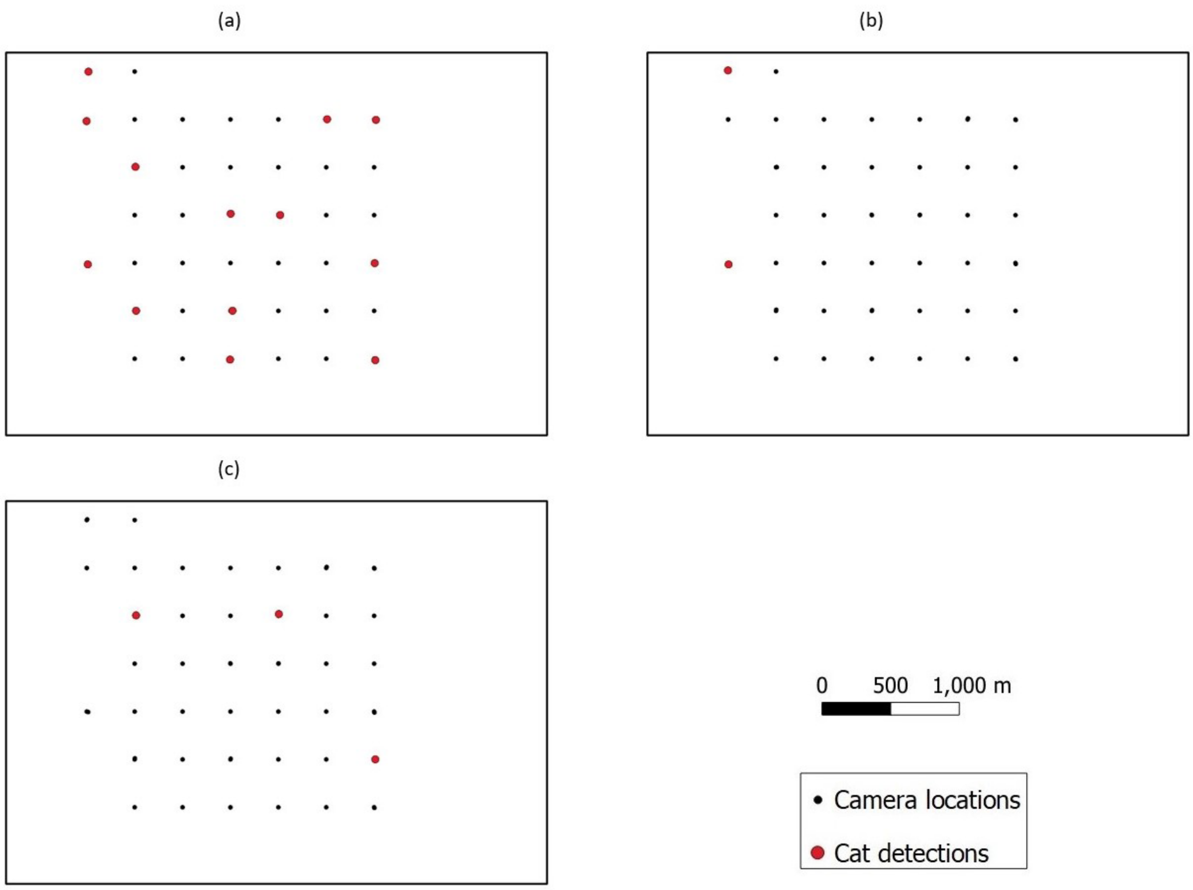

Figure 2. Camera detections of cats at Waitere station, pre-control (a) immediate post-control (b) and six months post-control (c). Small black dots indicate cameras with no detections, whilst large red dots indicate positive detections.

orange bullseye tabby was a large male that the landowner had observed before the control period. In the six-months post-control period, cats were detected at three camera locations (Fig. 2c). One cat was identifiable from the three locations of detections. Only one of the three locations of detections was within the grid, at a camera location 500-m from the edge of the study site. However, this cat did not match any previous detections, from either pre-control or immediately post-control, that we know of. This result demonstrates cat populations did not appreciably recover in the six months following the control period.

IMI method

Using the IMI method, we estimated there were 20.2 (± 2.8 SE) cats pre-control. The removal of 17 individuals led to an estimated three cats remaining immediately post-control, which equates to an c. 84% reduction. The IMI method was not used to estimate the number of cats in the six-month post control period, as the assumption of closure within the system was violated.

Discussion

Feral cat populations are routinely managed in New Zealand through lethal control for biodiversity outcomes (Parkes & Murphy 2003; Farnworth et al. 2011; de Burgh et al. 2021), and accurately evaluating the results of a control operation is important for feral cat management (Bengsen et al. 2011; Glen et al. 2016). We used camera traps to assess the effectiveness of the control operation for feral cats and the apparent rate of reinvasion six months later. This study suggests that the intensive ground-based control operation at Waitere station successfully removed most resident feral cats.

Some cats in the camera monitored population had uniquely identifiable markings. However, this was a small proportion, and many of the cats removed during the control operation were completely black. Thus, no attempt was made to use marked individuals as the major part of the assessment in this study (and none was required for this method of analysis). Nonetheless, identifying some of the feral cats on cameras in this study area helped us determine the difference between probable survivors and invaders.

The IMI method is unable to account for imperfect detection (Mackenzie 2005; Kellner & Swihart 2014); thus, results may be an underestimation of the true number of animals in the study area. However, this could be a simple method for field managers to use if they want to quickly estimate the success of a cat control operation.

We were surprised at the lack of apparent reinvasion six months after control, particularly as other studies have found relatively high rates of reinvasion into controlled areas (Short et al. 2002; Lazenby et al. 2015). Our result here is very encouraging for management of feral cats on NZ farmland. However, a note of caution must be made around these results. Sub-adult males may include dispersal movements within their home range of activity until adulthood (Langham & Porter 1991). Our monitoring period, which occurred six months post-control, was late spring in New Zealand. Our study period may have occurred before the majority of young males included dispersal movements in their activity patterns (summer and winter) (Langham 1992).

The intensive cat control efforts used in the current study clearly can have a high impact on the resident cat population. Nearby pastoral sites in the region with ongoing predator control (including pulsed cat control) have shown positive responses in some native biodiversity, such as native lizards (Glen et al. 2019). However, if these efforts aren't ongoing, and reinvasion occurs without careful management, then perverse outcomes may take affect (Lazenby et al. 2015; Cunningham et al. 2019; Palmas et al. 2020). If these efforts can be sustained, and even transitioned to complete elimination, with future reinvasion managed, then positive outcomes for biodiversity may increase further, as seen in island cat eradication programes (Campbell et al. 2011; Jones et al. 2016).

Acknowledgments

Many thanks to R Dickson and S Cave for logistical support, and to B Cheetham (Landcorp, Waitere Station) for site access and assistance. Thanks to Pouri Rakete-Stones and others for trapping and general knowledge throughout this study. Funding was provided by the Hawke's Bay Regional Council and Ministry of Business, Innovation and Employment for support.

Author contributions

All authors were involved in the design of the study. MN led the write up of results. MN, ASG, and PG completed field work and processing of footage. AMG and JR advised and completed the analysis.

Data and Code availability

There are no publicly available data associated with this article. There is no code associated with this article.

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Received: 26 September 2021; accepted: 28 July 2022
Editorial board member: George Perry